Sounding Rocket Working Group
December 20, 2006

NASA Sounding Rocket Operations Contract
(NSROC)

Wallops Flight Facility

SRWG Agenda - NSROC

NSROC State of Affairs	Rob Maddox
Mesquito Development	Dave Krause
Guidance, Navigation & Control	Walter Costello
Electrical Engineering	Shelby Elborn
Mechanical Engineering	Giovanni Rosanova
Conclusions	Rob Maddox

Program Manager

Rob Maddox

NSROC Programmatic

- Contract Status
  - Contract Year 8 almost complete
  - Maintaining very good PEB scores
  - New Govt. Contracting Officer – Pam Taylor
  - New Northrop Grumman Technical Services Sector
  - New local Contracts Administrator to start mid January
  - Recruiting several engineering positions
- Sub Contract Status
  - Bristol
    - Black Brant return to flight
    - Black Brant motor procurement
  - Saab – Completed delivery of 4 S-19L systems
  - Aerojet – Maintained minimal support for Mk VI systems
  - U. of Wisconsin – Ongoing support for ST5000
  - PSL – Ongoing support for instrumentation systems
  - Herley Industries – Significant order placed for radar transponders

NSROC Programmatic

- Challenges
  - Implement new technology
    - Attitude Control Systems
    - Vehicle configurations
    - Electrical Systems
  - Complex Missions
    - Methods outside experience envelope
  - Budget
    - Balancing staff, procurements, reimbursable workload
  - Schedule
    - Heavy manifest for 2007
    - Significant OT required for PFRR campaign

NSROC Programmatic

- Safety Close Calls
  - 3 close calls occurred involving ordnance shorting plugs
  - Independent investigations by NASA and NG
  - 32 corrective actions issued to prevent similar occurrences
  - 75% of correction actions have been implemented, remainder will be complete by end of December
- Operational Safety Supervisor (OSS) role being enhanced
  - OSS will be from independent work group - NSROC SQA & Code 803
  - OSS will perform more QA functions in addition to safety oversight
- Additional training for employees
  - Hazardous procedure upgrades
  - Proper procedure protocol
  - Task closeout documentation and photos

NSROC Programmatic

- Recent Reimbursable Projects (since last SRWG)
  - US Navy Aegis FTM-10: Two Terrier Orion missions
  - US Navy Aegis FTM-11: One Terrier Oriole mission
  - US Army Infrasound 5&6: Two Orion missions
  - US Army THAAD: Two Black Brant IX mission
  - LIDS Manufacturing Task
  - HyBolt TM and T&E Services
  - RPCS+ for WMSR
- Total of 21 reimbursable projects for Contract Year 8 (Feb 06 to Jan 07).

NSROC Programmatic

- New Business Opportunities (since last SRWG)
  - US Navy Aegis FTM-12: Two Terrier Orion missions
  - US Navy Aegis FTM-12a: Emergency Terrier Orions!
  - US Navy Aegis FTM-13: Two Terrier Orion missions
  - US Navy JFTM-1: One Terrier Oriole mission
  - USAF Airborne Laser MARTI 1&2: Two BBIX missions
  - USAF Airborne Laser: Five Terrier Lynx missions
  - MDA LeClair: One Black Brant IX mission
  - US Navy TSER Program – NGTS Proposal Pending
  - MDA DET LCAT Program – SRPO Dialog
  - US Navy SCSC Fleet Training Rockets – Early Discussions
  - JPL New Millennium – Anxiously awaiting the NMP ST-9 Decision
  - Langley – HyBolt support underway

NSROC Programmatic

- Student Outreach
  - 2006 students (Spring 4; Summer 6; Fall 3)
  - 2007 (Spring 5; Summer 8; Fall 2)
  - 55 students have participated in this program; NSROC has hired 5 Intern/Coop graduates as full time engineers; another works for NG Space Systems in CA; 2 have achieved Doctorates; 6 have obtained or are pursuing Masters Degrees.
  - ESCC Intern Program: 2 Interns now FTE NSROC Techs
  - NSROC Extern Program begins 1/8/07 with 2 VT students.
  - Program is a model for Royce Cutler's USAF Program in CA
  - 5 NSROC employees have joined Wallops' Character Counts Team, an outreach for local schools.

NSROC GNC

Walt Costello

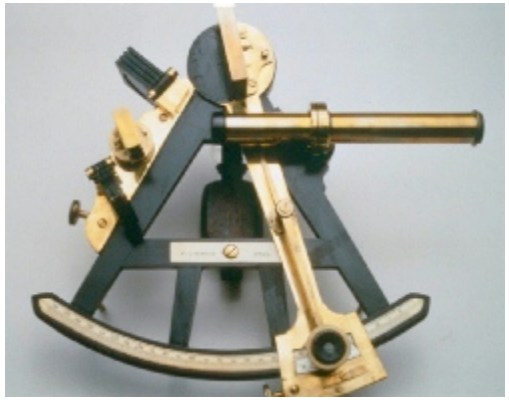
GNC – Walt Costello

- Celestial ACS
  - Test Flight: ST-5000 Anomaly Report
  - Successful Cash Launch
  - ST-5000 Focus Problem
  - Celestial Mission Schedule
  - Celestial Challenges
- Boost Guidance Systems S-19A, S-19D, and S-19L
- Audenaert 36.237/36.238 Successful acrobatic magnetic ACS
- GPS Velocity Vector Input to NIACS
- GLN-MAC Attitude Determination Performance
- Digital Magnetometer Performance
- Poker Flat Campaign, 2007
- Informal Evaluation – NSROC ACS vs Vendor ACS

12.058 ST-5000 Anomaly AIB Report

- ST-5000 Rebooted at Motor Burnout and rebooted again during first reboot
  - Caused by pinched wire which momentarily dragged down 5V power enough to cause reboot (only had to sag 0.25 V)
  - After Reboot, ST-5000 came up in anomalous state and failed to communicate with ACS
  - ST-5000 software defects have been found and corrected
  - CACS – ST5000 handshaking improvements have been made
  - ST-5000 design improvements pending - engineering structure sufficiently robust for now – electrical improvements also pending.
  - System Engineering improvements made – working more closely with UWISC

- Otherwise Celestial ACS performance was nominal
  - GLN-MAC performance good,
  - Stars seen on ST-5000 video downlink
  - Uplink worked very well.



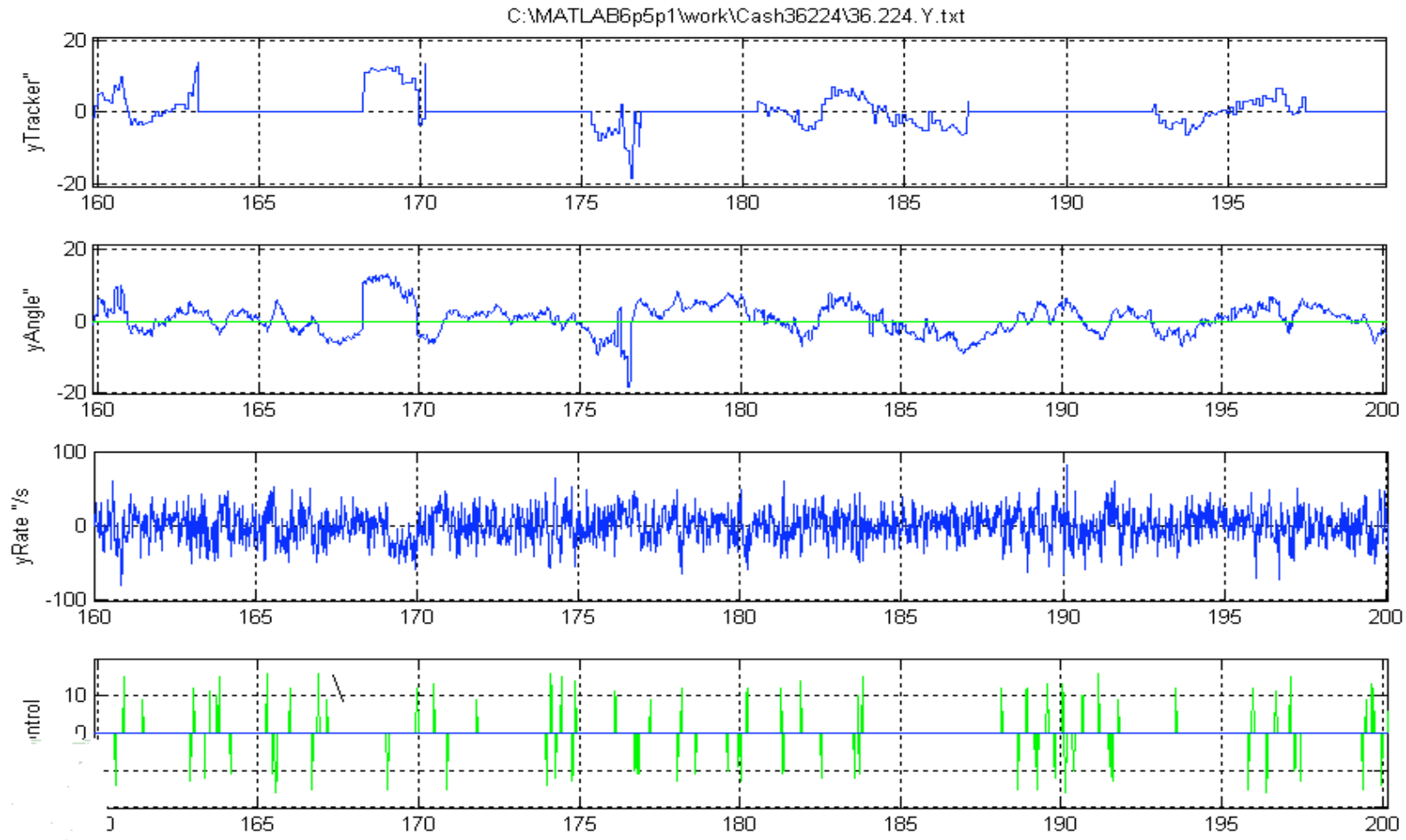
Cash 36.224

- Free test flight for Celestial ACS (thank you, Dr. Cash!)
  - Was possible to meet Comprehensive Success with telescope, uplink & GLN-MAC only (same as 12.058 ACS)
  - Was possible to meet minimum success with GLN-MAC only
- ST-5000 performed many lost-in-space successfully
  - Focus problem caused difficulty differential tracking
  - Algorithm problem caused individual stars to be dropped, resulting in loss of track. Number of stars tracked dropped from high of 14 to below 3 (minimum for track).
  - Unlike 058, this problem is well understood
- Comprehensive success was achieved
  - Between acquisitions, ACS held well on GLN-MAC
  - In all other respects, including uplink, performance was nominal
  - System is capable now of +/- 10 arcsec performance
  - Focus and algorithm problems are well understood
  - We have a great deal of confidence they can be fixed.

Cash 36.224
ST-5000 Focus problem

- ST-5000 has very short focal length (~F1)
  - Required for adequate photon counts
  - Extremely sensitive to small variations
- Focus is slightly different in air and vacuum
  - Temperature and vibration may also cause changes
  - ST-5000 is deliberately defocused to improve centroid accuracy
    (thus, there is not a requirement for perfect focus)
  - Differences in focus must be accounted for
  - UWISC is developing optical tool to use in testing and setting focus
- Differential tracking algorithm is not sufficiently robust
  - Better centroid algorithms and/or improvements to current algorithm are under investigation.
  - Three validity tests – criteria are probably too severe
  - Drift can cause great changes as pixel boundary is crossed
  - When a star is dropped it is gone forever – considering maintaining tracking list
  - Considering 2-D Gaussian fit instead of 1-D parabolic fit.
  - Considering total flux test instead of max pixel flux (less variability)

Cash 36.224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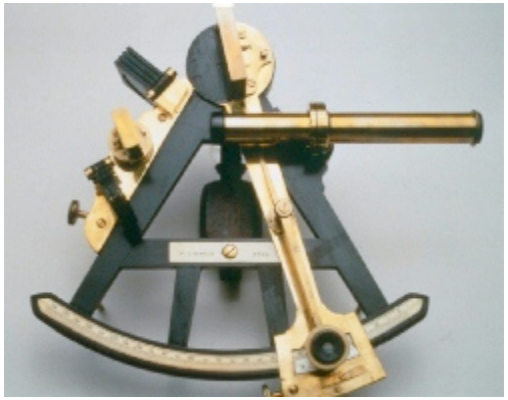
Scheduled Celestial Missions

- 12.059 Costello Mar 2007 (test flight)
  - ST-5000 focus problem
  - Pressure Controller fine pitch-yaw control for Chakrabarti
  - LN-251 fine rate sensor
- 36.225 Chakrabarti Mar 2007
  - Must acquire within 1 arc-sec
  - Very precise control based on science provided “perfect” error signal
  - Cooled shutter door is presenting challenges
- 36.220 McCandliss Jun 2007
  - Target position within +/- 5 arc-min
  - Command Uplink to 10 arc-sec Slit
- 36.207 Cruddace TBD (AeroJet OR Celestial)
  - Less than 1 arc-sec/sec jitter
  - Less than 0.2 arc-min/min drift
  - +/- 2 arc min target
- 36.226 Bock Feb 2008
  - 3 arc-sec max error in 20 seconds
  - Side looking ST-5000
- 36.235 Harris Jun 2008
  - 20-30 arc-sec



Celestial ACS Challenges

- Fine pointing performance (~ 1 arc-sec) requires upgraded rate gyros.
  - Near-term approach: Retain GLN-MAC
  - Add LN-251 Digital IMU as precise rate gyro
    - 2 on order - delivery was 22 Dec 06 now slipped 30 to 45 days
    - Have “loaner” LN-250 (3” vs. 5” loop on LN-251)
- Redesigned tri-level pneumatics for fine pointing
  - Axially-mounted valves at the nozzle block – reduces ullage.
  - Very fast valves for fine pointing have been delivered
- Testing Pressure Controllers as alternate approach
  - Fast valves still nonlinear and may have too much vibration for Chakrabarti
  - Testing Alicat Scientific Pressure Controllers using differential thrust
- Chakrabarti is a particularly challenging mission
  - But it IS possible without LN-251
  - Need to get into 10 arc-sec box on our own
  - Then use experimenter’s “perfect” error signal
  - To test closed-loop performance – will feed back Lackey signal
  - Upgraded Lackey is on order (increased precision)

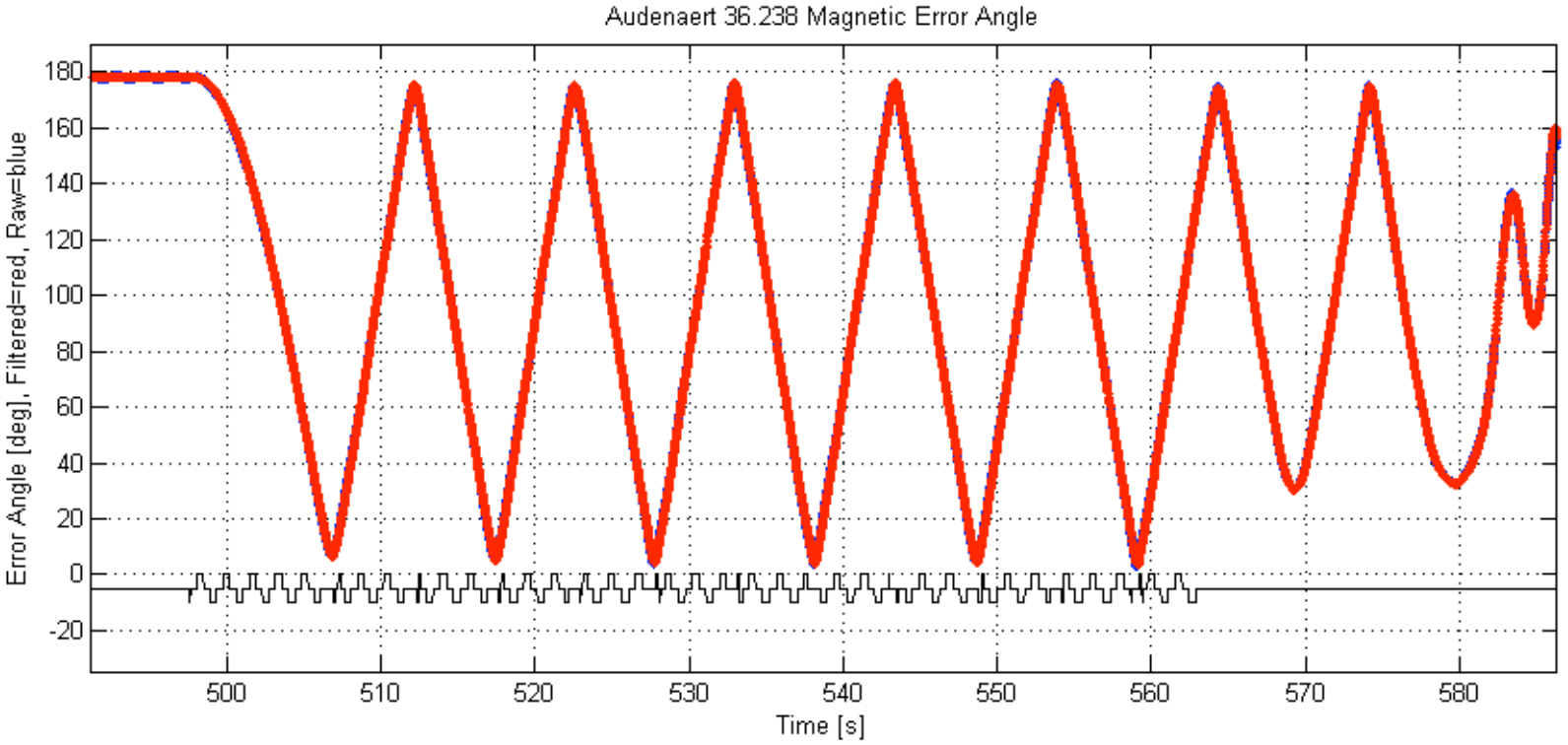
GNC – Boost Guidance Systems

- 1 S-19A system left - scheduled for McCammon
  - 2 MIDAS gyros left – at SVC for refurbishment
- 3 S-19D w/DMARS
  - Two flew on Cash and Woods – are being refurbished
  - One ready to fly
  - Approx 4 month refurbishment cycle for S-19D
- 4 S-19L systems have been delivered – will order one per year
  - Audenaert 32.237 & 36.238 both flew S-19L – refurbishment complete
    - On 238, made spectacular save when Terrier fin was lost
  - Strap-down LN-200 may be only adequate for rail attitude hold.
  - More reliable without gimbal – also faster refurbishment
  - Reimbursable missions made procurement possible
- S-19G design available – could do IIP steering (DS-19)
  - Both designs build on existing DS-19 design & software, replace DMARS, and Incorporate SAAB Guidance Processor Unit (GPU) which accepts raw LN-200 data
  - No S-19G have been manufactured

Audenaert 36.237 & 36.238

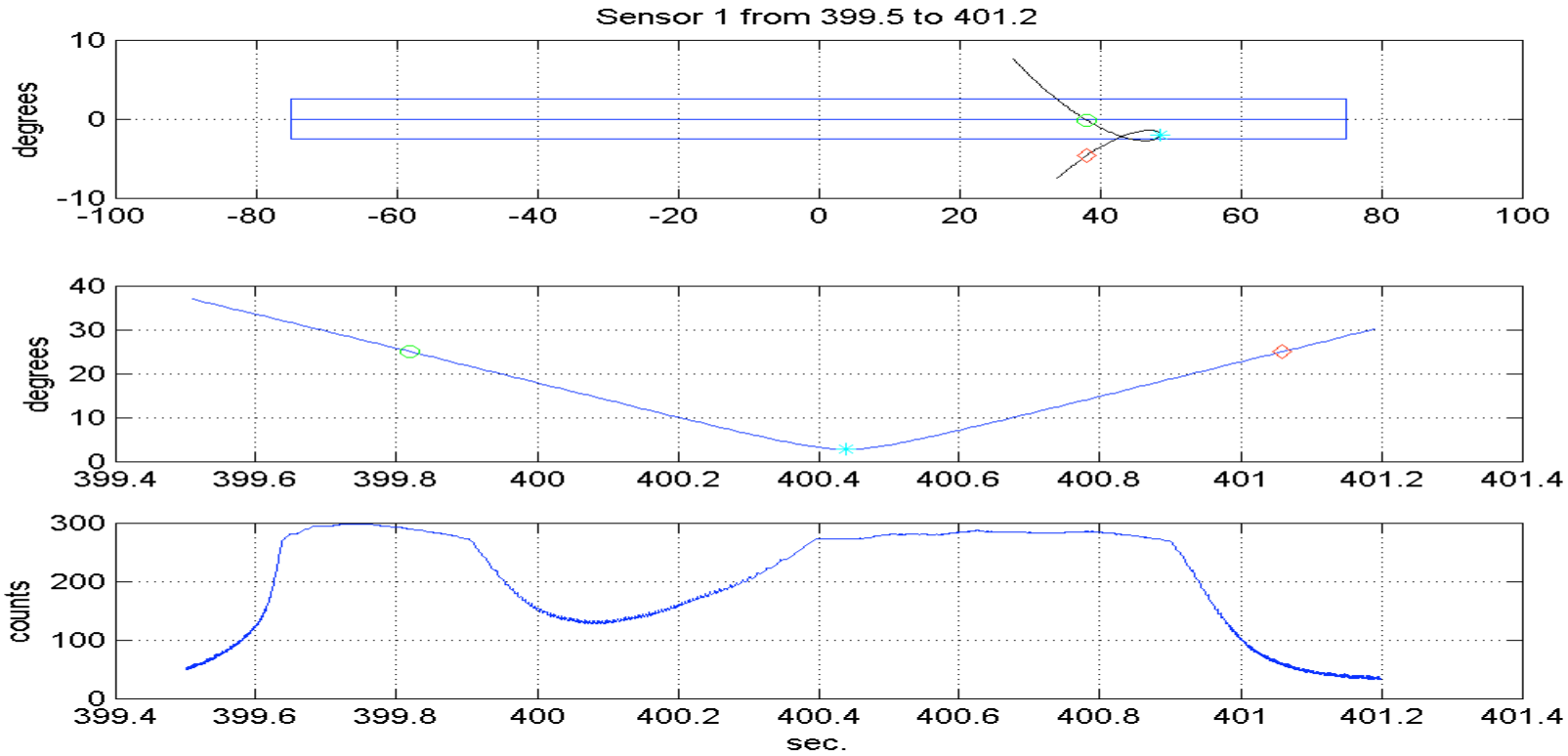
- Reimbursable mission with compressed schedule
- First two flights of S-19L – this mission paid for manufacture
- NMACS control to present targets to THAAD radar
- No TM Gyros (to save money)
- Attitude determination with sun sensors & magnetometer
- Complex maneuvers including controlled tumble of forward payload
- Un-instrumented aft payload with pneumatic impulse tumbles
- Ten sun sensors on aft payload
- Forward payload recovered – both NMACS to be re-flown on Larson
- Customer very pleased
- “Soldiers yet unborn are in your debt”

Audenaert 36.238



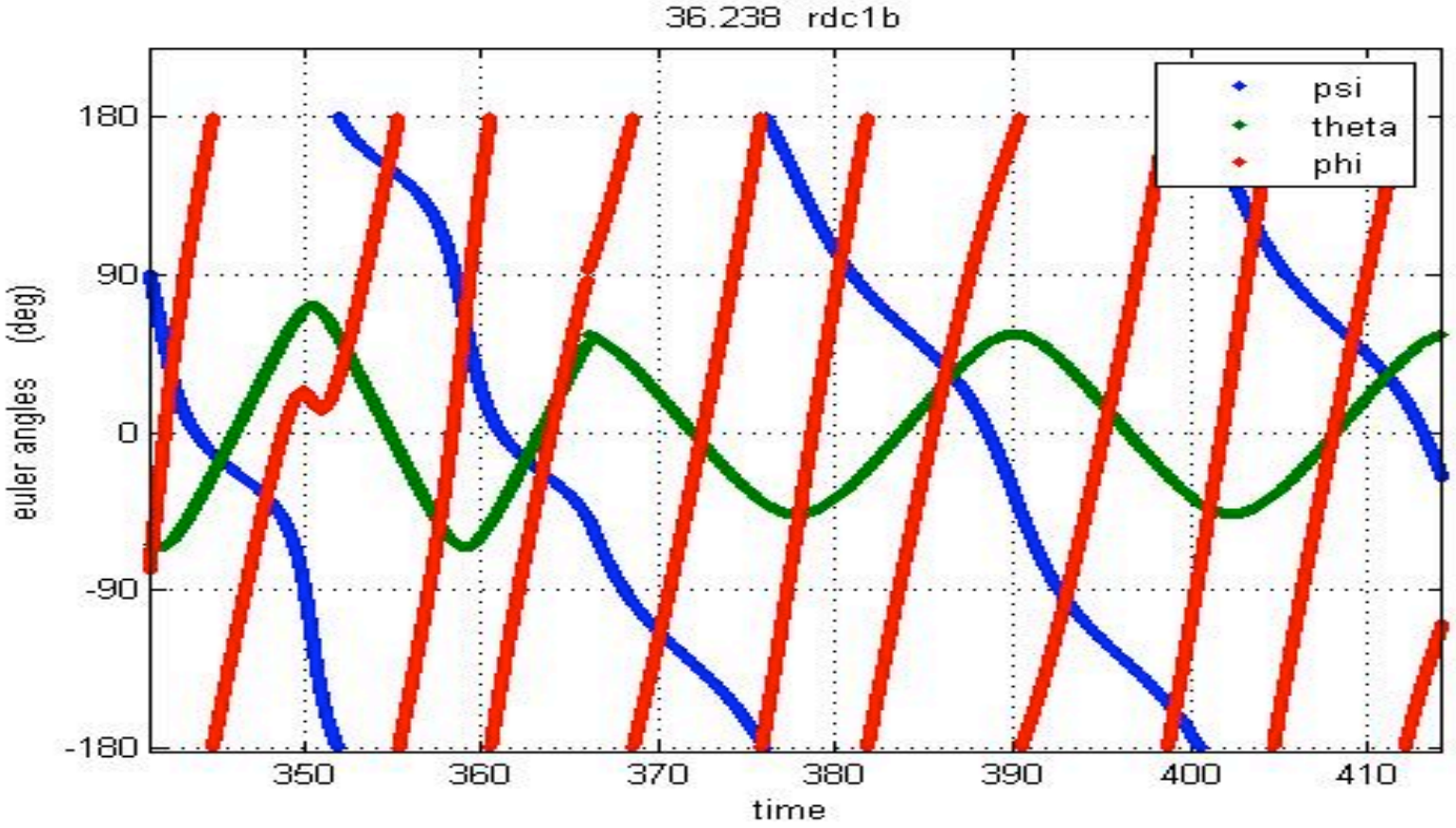
- Forward payload controlled tumble
- Tumble continued after control off (as expected)

Audenaert 36.237
Aft Payload Tumble



- Interesting solar sensor pulse
- Almost 2 second pulse caused by tumbling trajectory

Audenaert 36.238

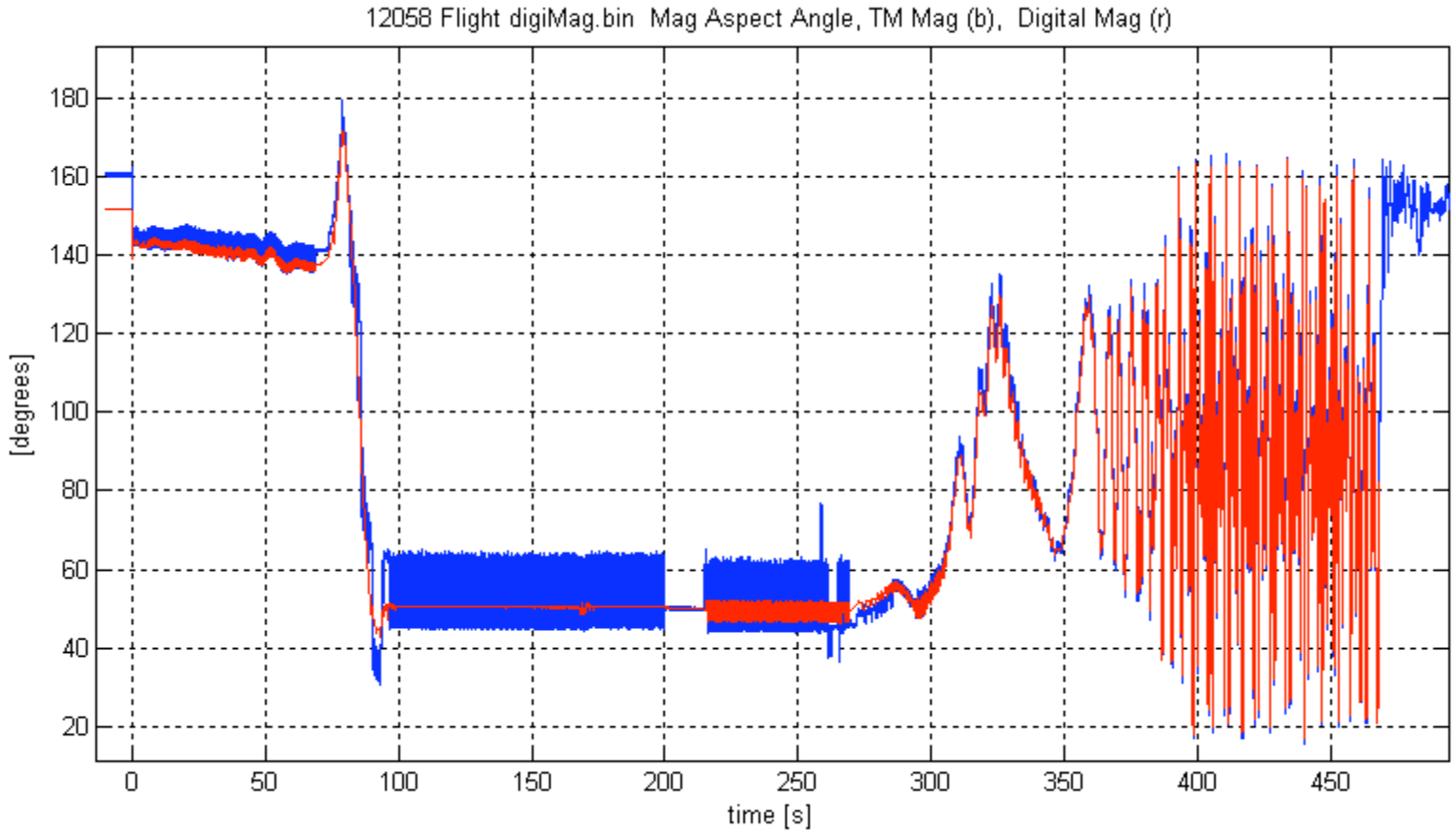


Aft Body Tumble - NSROC(a) Attitude Solution

GPS Velocity Vector Input to NIACS

- Seybold 41.068 WSMR April 5, 2006 (successful test flight)
- Earle 36.218 Wallops Oct 2006 (no science, no launch)
- Craven 35.037 Poker Flat Feb 2007 (input to experiment)
- Earle 36.218 Wallops April 2007 (may slip to fall)
- Robertson 41.069/70 Andoya June 2007

Digital Magnetometer Performance



Poker Flat Campaign 2007

- Integration went well – no significant ACS problems
- Larson –
  - 2 NMACS with TM Gyros
  - Similar to Joule
  - Also 2 chemical rockets
- Lessard –
  - NIACS
  - Complex sub-payloads with Horizon Crossing Indicators (HCI)
- LaBelle –
  - NMACS & TM Gyro & HCI
  - Straightforward mission
- Craven –
  - NIACS & Digital Magnetometer
  - Trajectory modification similar to Conde
  - Velocity vector input to experiment
  - Also three instrumented chemical rockets with HCI

SRWG asked for NSROC ACS Comparison to Vendor ACS

- **NMACS vs Space Vector**
  - Comparable mass, volume, power
  - Performance improvements include
    - Magnetometer software filter removes need for auto-bias
    - Performance assessments (accuracy) so far are very good
    - Software allows more flexibility and variety of maneuvers
    - HILTS enhances software testability, allows software change in field
  - Telemetry much improved
    - Digital serial data provided on real-time GUI
    - Real time data available on air bearing and IN FLIGHT!
    - Data available immediately after flight, just tell us what you want
  - Ease of use, flexibility and reliability
    - 14” NMACS design available and has been used
  - Extensions available (all we need is THE STATED REQUIREMENT)
    - Mini system for sub payloads
    - Off-B attitude control (using HCI or sun sensors)

NSROC ACS
Compared to Vendor ACS

- **TM and ACS Gyro: GLN-MAC vs MIDAS**
  - Comparable mass, volume, power (slightly longer)
  - Major performance improvements
    - Drift spec 1 degree per hour (most test to _ degree per hour)
    - Compare to MIDAS 3 degrees during your flight
    - We are experiencing _ degree from launch (mostly launcher variability)
    - Software allows more flexibility and variety of maneuvers
  - Telemetry much improved
    - Digital serial data provided on real-time GUI
    - Real time data available on air bearing and IN FLIGHT!
    - Axes are always orthogonal – no special data reduction requirements
    - Data available immediately after flight, just tell us what you want
  - Ease of use and Reliability
    - NO LIMITATION ON MANEUVERS
    - No danger of tumbling
    - MINIMAL IN-HOUSE REFURBISHMENT

NSROC ACS
Compared to Vendor ACS

- **NIACS vs Space Vector**
  - Comparable mass, volume, power – flexible pneumatics volume
  - Major performance improvements
    - Drift spec 1 degree per hour (most test to _ degree per hour)
    - Compare to MIDAS 3 degrees during your flight
    - We are experiencing _ degree from launch (mostly launcher variability)
    - Software allows more flexibility and variety of maneuvers
  - Telemetry much improved
    - Digital serial data provided on real-time GUI
    - Real time data available on air bearing and IN FLIGHT!
    - Gyro axes are always orthogonal
    - Data available immediately after flight, if you tell us what you want
  - Ease of use and Reliability
    - No limitation on maneuvers
    - No danger of tumbling
  - Major Extensions Available
    - Velocity Vector Steering
    - Digital Magnetometer Steering
    - Can use any vector input for steering – including from the experiment
    - 14” ACS available (Robertson)

NSROC ACS
Compared to Vendor ACS

- **Celestial vs AeroJet**
  - Comparable mass, volume, power
  - We are losing Ron Hall expertise (but we stole Neil Shoemaker)
  - Still in development
    - ST-5000 currently has focus issues, but Ball single-star tracker is obsolete
    - ST-5000 issues are well understood and resolvable
    - GLN-MAC inferior to analog TRIGS - upgrading to LN-251
  - Pneumatics developing from previous WFF system
    - Commonality with NIACS
    - Pressure controller under development for precise pointing
  - Enhanced testability
    - Laser Autocollimator including precision control drive
    - Star tracker “learn” mode
    - ACS cradle with motor driven by control system
    - Focus tool (under development)

NSROC ACS
Compared to Vendor ACS

- **NSROC(a)**
  - No vendor equivalent (except for Horizon Crossing Indicator)
    - Can obtain attitude data without Gyro
    - Sun sensors from ARL are performing very well
    - New Horizon Crossing Indicators (HCI) minimized in size
- **SPARCS**
  - No vendor equivalent
  - Excellent historical performance
  - Undergoing continuous improvement
  - Evaluating digital rate sensors
- **S-19**
  - Still vendor supplied (SAAB)
  - Procured S-19L version: LN-200 with NO GIMBAL
  - S-19L has faster refurbishment cycle and is cheaper than S-19D

NSROC ACS
Compared to Vendor ACS

- **Cost considerations**
  - No overall detailed cost study has been undertaken
  - Budget austerity and Inflation would have to be considered
  - Now the funds flow to Sounding Rocket infrastructure instead of vendors
  - Vendor overhead is avoided
  - Vendor profit is avoided
  - Sounding Rocket engineering capability and innovation is enhanced
  - Sounding Rocket program flexibility and responsiveness is enhanced

- **Bottom Line**
  - “Skunk Works” approach is faster, cheaper, and often even better
  - It’s harder but it’s more fun
  - Please stretch your imagination and give us some interesting requirements
  - But we have enough sub-arc-second projects for a while ☺

Thank You For Your Support

- NSROC ACS stands ready to support experimenters worldwide.
- Questions?
- Comments?
- Observations?

Electrical Engineering

Shelby Elborn

Electrical Engineering

Wide Bandwidth, High Efficiency S-Band Transmitters

Issues

- Currently any PCM downlink operating over ~1.5 Mega Bit Per Second requires using a 10-Watt S-Band transmitter whether we are going 100 km or 1000 km.
- The 10-Watt transmitter requires 3.1 Amps to operate and generates ~75 Watts of heat
- Existing 2, 5 & 8 Watt narrowband transmitters are not frequency agile.

Solution

- Procure new higher bandwidth, higher efficiency frequency agile units

Program Benefits

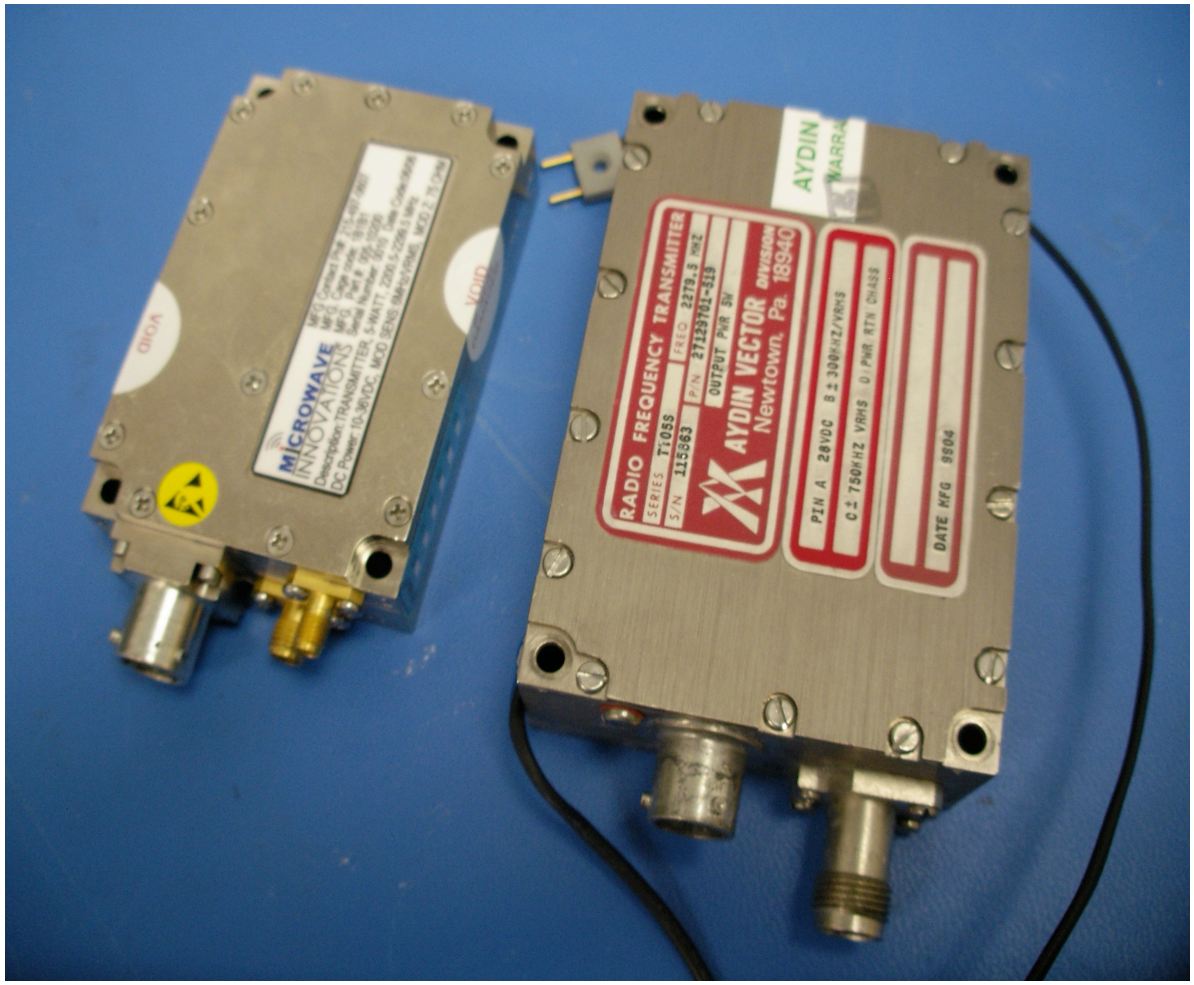
- Reduced payload weight due to smaller battery and heat sinking mass requirements.
- Frequency agility allows only having to purchase/stock one model per RF power rating

Status

- 5 Each 2 Watt and 5 Watt received. Environmental qualification testing completed on 5 Watt First Article and in process on 2 Watt First Article
- 2 5 Watt units being flown on 40.020 Lessard
- 2 Watt units planned for use in the new Mesquito payloads

Electrical Engineering

Wide Bandwidth, High Efficiency 5 Watt S-Band Transmitter



Electrical Engineering

Wide Bandwidth, High Efficiency 2 Watt S-Band Transmitter

Electrical Engineering

Mesquito PCM

Program Benefits

- System designed and built in-house allowing mechanical design to be custom tailored to Mesquito application.
- Low cost by fabricating system in-house.

Implementation

- Designing with a modular approach with stackable add-on data modules.
- Presently targeting 16 analog inputs per module with 48 channel max and configurable serial digital or asynchronous data module with 2 inputs each.

Breadboard Test Results

- Synchronous serial digital data at rates up to 2 M BPS
- Asynchronous data input rates up to 115.2 K baud
- Analog data with 16 bits resolution

Status

- PC board layout for all boards has begun.

Electrical Engineering

Mesquito Power Switching

Program Considerations

- Traditional mechanical relays are too large for use in the extremely space and weight limited Mesquito payload
- Mechanical relays may not survive the 100-120 G's acceleration.
- Two mechanical relays and sockets are ~$500 whereas 2 solid state switches are ~$25

Implementation

- Surface mount circuit technology
- Device selected rated for 4.5 Amps

Breadboard Test Results

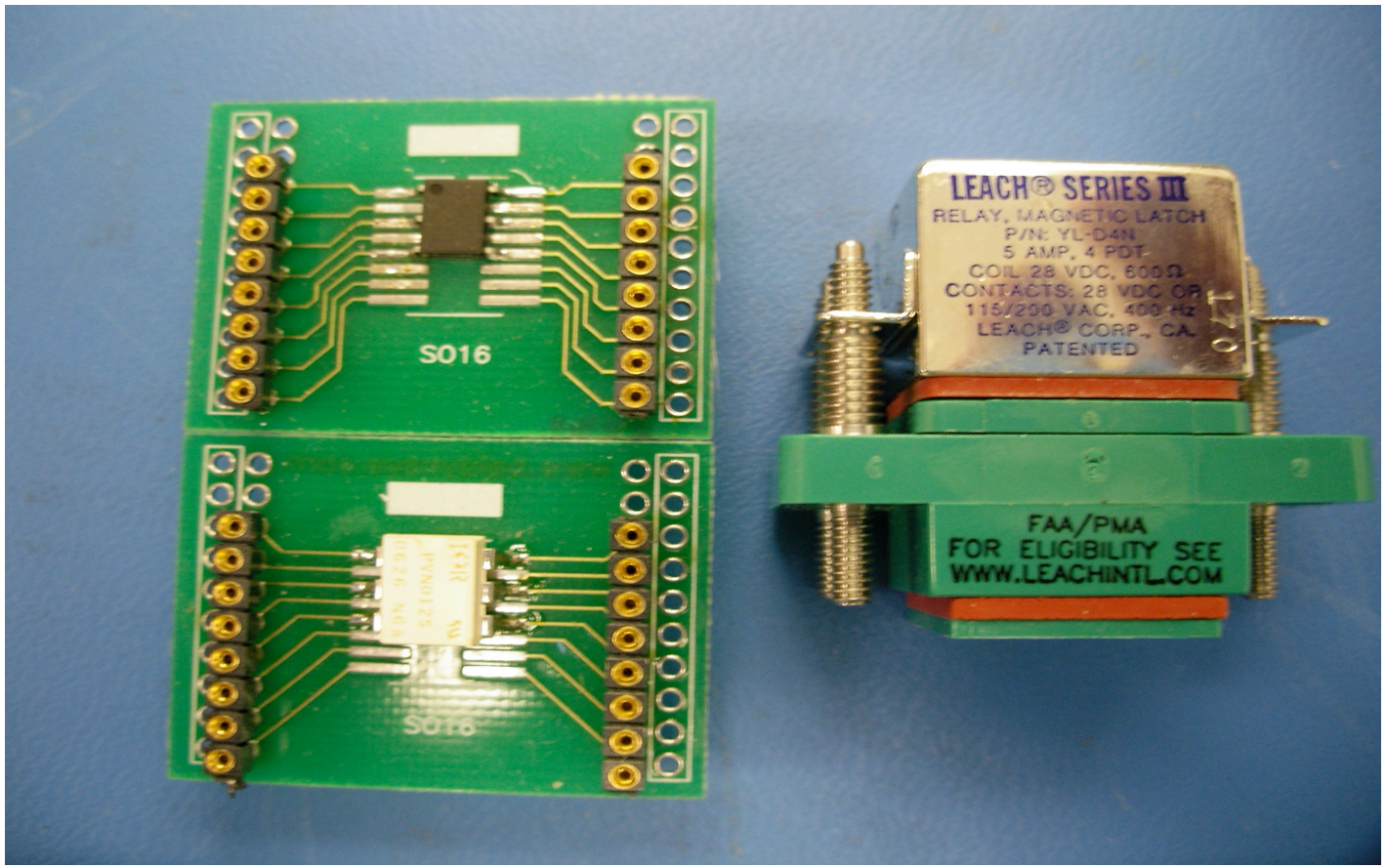
- Tested at 4 Amps continuous for 4 hours
- Tested 2 hours while switching on and off at 1 Hz while loading to 4 Amps

Status

- Schematic design of TM and Exp power switching and distribution in final design.

Electrical Engineering

Mesquito Power Switching



Electrical Engineering

Mesquito Current Sensing

Program Considerations

- Traditional current sensors are too large for use in the extremely space and weight limited Mesquito payload.

Implementation

- Surface mount circuit technology using high power low resistance (.010 Ohm) voltage dropping resistor with Kelvin connections.
- Circuitry designed for monitoring 0-5 Amps.

Breadboard Test Results

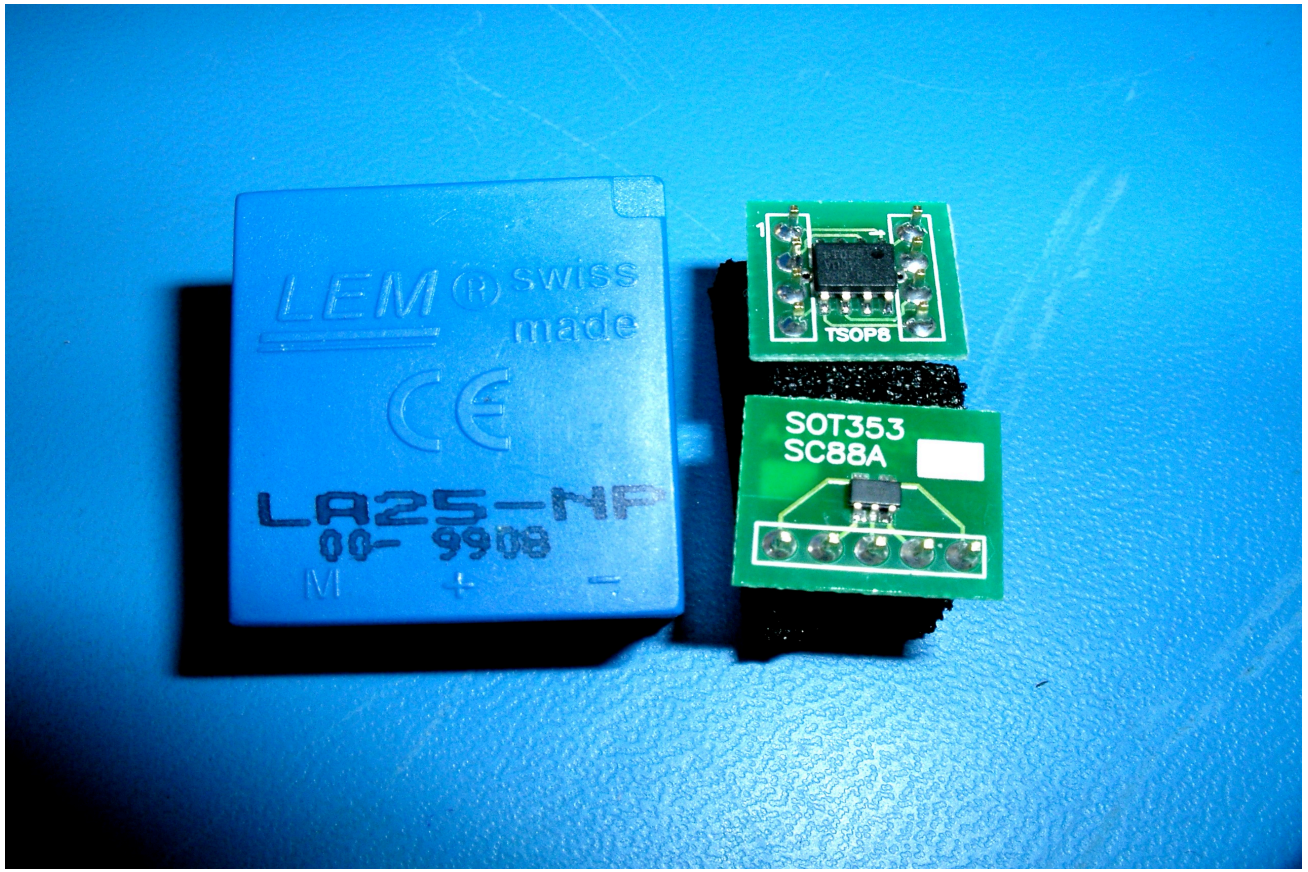
- Extremely linear over the 0-5 Amp range.
- No low end sensitivity issues as noted with present Hall effect sensors.

Status

- Schematic design of current sensor and operational amplifier completed.
- Design incorporated on same PC board as TM & Exp. solid state power switching circuitry.

Electrical Engineering

Mesquito Current Sensing



Mechanical Engineering

Giovanni Rosanova

Mechanical Engineering

- Vibration Testing Loads Investigation Update
  - Non-advocate Review held on 8/16/06.
  - Chaired by Chuck Brodell; AETD and Science representation on the Panel
  - Dr. Ricky Stanfield presented data, analytical approach, and proposed new test philosophy.
  - Follow-on meeting with AETD to discuss alternate analytical approach that is more in line with GSFC and other centers. Requires more flight data to build statistical confidence.
  - Panel does not recommend radical changes to the current test philosophy and loads at this time. Incremental, necessary, and independently reviewed changes recommended.
  - Panel recommends further investigation into shipping loads and other dynamic inputs.

Mechanical Engineering

- Supporting multiple efforts
  - Final stages of BB Mk1 Return to Flight: Reports, analyses, etc. Working with Bristol and SRPO.
  - MLRS development
  - Close Call Corrective Action Plan effort
  - Mission-specific issues
- Future efforts
  - More new vehicle development: Taurus replacement, Patriot
  - Next generation Flight Termination System – Joint effort with NASA: AETD, SRPO, Safety

Conclusions

- NSROC is committed to continuing the SRPO mission and program successes. 2006 has been a good year for Sounding Rockets.
- NSROC's Primary Goal is unchanged:
  - to satisfy the Code S PI mission requirements.
- NSROC is committed in expanding the technical innovations while
  - Meeting the requirements of the PIs
  - Maintaining a cost effective environment
  - Making effective use of the in-house talent, experience and hardware.
- NSROC's early receipt of the SRWG findings is important for future growth planning.